Chemical equilibrium versus reaction rate descriptions of Fisher scaling

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There are two competing interpretations of the Fisher scaling of multifragmentation data [1,2]. The first is the very natural explanation in terms of chemical equilibrium between a gas and a liquid [3]. The second explanation is a reaction rate picture supported by the observation of Fisher scaling of complex fragments emitted from compound nucleus reactions [4].

Since compound nucleus decay rates (widths Γ) can be calculated using standard theory, then the first chance emission yields from a compound nucleus can be used to determine the properties of the nuclear vapor. In other words the first chance emission yields $\langle n \rangle$ can be written

$$\langle n \rangle \propto \Gamma \propto e^{-B/T} \sim \bar{v}c \tag{1}$$

where $\bar{v}$ is the mean fragment velocity and c is its vapor concentration. It is noteworthy that the same decay width Γ which controls the first chance emission yields also controls the mean emission times (τ) for fragment emission since

$$\Gamma\tau \approx \hbar, \tag{2}$$

and therefore

$$\tau \propto \frac{1}{\Gamma} \propto \frac{1}{\langle n \rangle} \propto e^{B/T}. \tag{3}$$

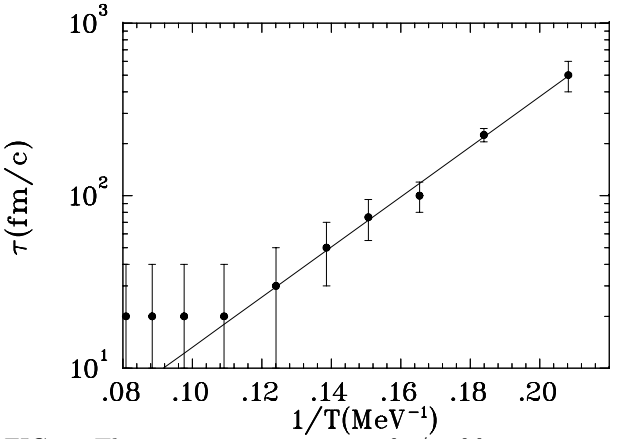

FIG. 1. The mean emission time in fm/c of fragments with atomic number $Z = 4 - 9$ is plotted versus inverse temperature for the reaction π+Au at 8 GeV/c [5,6]. The line is a Boltzmann fit to the emission times.

How do we tell whether the chemical equilibrium picture or the reaction rate picture is the relevant description of the ISiS and EOS data sets? The necessary information has been provided by the ISiS collaboration. They have measured the mean emission time for fragment emission as a function of excitation energy [5,6]. We have plotted the mean emission times as a function of $1/T$ in Fig. 1. We use the Fermi gas approximation to map excitation energy to temperature. We observe that the lifetimes are well described by a Boltzmann factor, indicating a thermal reaction rate picture.

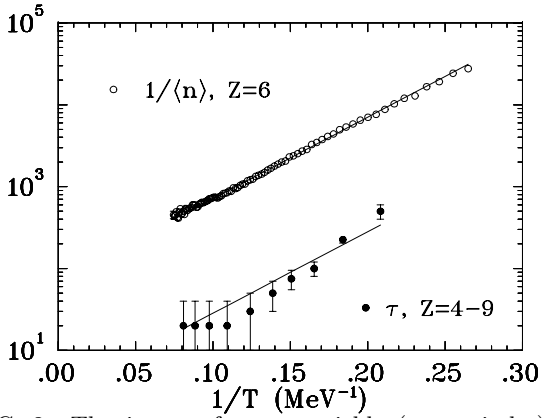

FIG. 2. The inverse fragment yields (open circles) and emission times (solid circles) are plotted as a function of inverse temperature for the reaction π+Au at 8 GeV/c [5,6]. The line is a Boltzmann fit to the inverse yields. The same Boltzmann factor is used to describe the emission times.

Furthermore, the lifetimes are consistent with the same Boltzmann factor that controls the yields. In Fig. 2, we have plotted the inverse yields of carbon on the same plot as lifetimes determined for $Z = 4 - 9$ as a function of inverse temperature. The Boltzmann factor which describes the yields (the fit to the open points) can be used to describe the lifetimes (solid points). Not only do the lifetimes appear statistical, they are also governed by the same Boltzmann factor as that controlling the yields. Consequently, we are left with a picture very similar to compound nucleus decay which describes the ISiS data up to the critical temperature.

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